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SATELLITE BROADCASTING: optimal distribution of frequency channels, orbital positions and polarisations

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Summary

The report discusses some of the factors affecting the viability of a plan of frequency assignments for satellite broadcasting and shows that the data used by the planner leads logically to a regular distribution of channels, orbital positions and polarisations.

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SATELLITE BROADCASTING: OPTIMAL DISTRIBUTION OF FREQUENCY CHANNELS, ORBITAL POSITIONS AND POLARISATIONS

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1. Introduction

The planning of a system of direct broadcasting from synchronous satellites to about 45 countries in Europe and North Africa has been under consideration for several years. The European Broadcasting Union (through its Consultative Group on Satellite Broadcasting and Sub-Group K3 of its Technical Committee) is co-ordinating the work of participants, taking political preferences into account where these are known and technically acceptable. In view of the shared orbital arc, it is also considered important to extend the scope of planning studies to include the whole of the African Continent.

In ITU Region 1,[1] which embraces Europe and Africa (including the whole of the USSR), the band of frequencies between 11·7 GHz and 12·5 GHz has been allocated to the broadcasting-satellite service, shared with terrestrial broadcasting and fixed services. It is hoped to demonstrate that a satisfactory scheme of channel assignments to about 100 countries for satellite broadcasting in the western part* of Region 1 can be established before the start of the World Administrative Radio Conference for Broadcasting Satellites in January/February 1977. If a plan can be agreed at an ITU conference, the services operating according to such a plan would be given precedence (Note 405BA of the Radio Regulations[2]).

The construction of a practicable plan of channel assignments to each of a large number of countries involves the optimisation of many variables as shown by some early studies.[3] A number of plans for up to 45 countries have already been produced and analysed[4] by computer programs into which all the data and constraints may be introduced. However, although satisfactory plans are within sight, not all the individual preferences have yet been met in respect of groups of countries requiring a common orbital position.

It is therefore suggested that a valuable simplification of approach is desirable, and it will be shown that there are advantages in establishing a fairly rigid framework of rules before any particular assignments are made. Within such a framework, the formulation, discussion, adjustment and analysis of a proposed assignment plan would be made easier. The consequent loss of flexibility must be made unimportant by care in the choice of the basic framework and it is shown that, by a series of logical steps, a rational choice can be made which gives satisfactory options to planning in Regions 2 and 3.

The starting point for the framework is the presently-accepted data for the antenna reference patterns and protection ratios, coupled with the assumption that a limited series of equally-spaced orbital positions will be used for satellite broadcasting. It is then possible to prescribe necessary geographical separations for countries which share the same or adjacent frequency channels. Following this the ideal antenna reference patterns are reconstructed from a consideration of the model in order to reveal the non-essential features of the original data.

The technical data used in this report are those currently proposed for planning by the EBU and differ somewhat from those published in CCIR.[5]

2. Antenna reference patterns

The most important factor in planning is the discrimination against interference obtained by the transmitting and receiving antennae; the data which has been provisionally accepted within the EBU for planning purposes is given in Fig. 1. The curves represent the upper limit for the response of the antennae, normalised to the maximum on-axis value. Presented in this way, the data is well-suited to the needs of the antenna designer or the computer analysis programmer.

For more immediate application to planning it is, however, useful to have a presentation which, for an interference path from a satellite to a receiver, indicates the combination of off-axis angle from the satellite and off-axis angle at the receiving antenna that will give various fixed reductions of interfering signal level, relative to the signal level that is obtained with on-axis operation of both antennae with a co-channel and co-polar signal. In Fig. 2, therefore, the two sets of data of Fig. 1 have been combined to show lines of constant signal-to-interference ratio relating the two antenna angles. In preparing these contours, the value of the ratio between the minimum wanted signal and its maximum value at the beam centre has been assumed to be 3 dB; also the wanted and interfering signals are assumed to have equal maximum e.i.r.p.'s and to suffer equal path attenuations. A fixed allowance of 3 dB has therefore been included to allow for results at the edge of a service area. In addition, it has been assumed that rainfall will generate a signal of the opposite polarisation at a level 30 dB lower.

Fig. 2 is useful for planning if, in any systematic plan, both the frequency separation of adjacent channels and the angular separation of adjacent orbital satellite positions are fixed. Fig. 2 has a subsidiary scale of degrees relating to the beamwidths off-axis; this assumes that the beamwidth of a typical receiving antenna (ϕ_{OR} in the diagram of Fig. 1) is 2·4 degrees, corresponding to a circular aperture of about 75 cm diameter, as indicated for individual reception in CCIR Report 215-3.[5]

A regular arrangement of orbital positions will lead to a set of fixed values for the abscissa of Fig. 2 as indicated by the subsidiary scale, as an example, for an orbital spacing of 7·5 degrees corresponding to 3·1 beamwidths at the receiving antenna. Moreover, the values of interference reduction shown by the curves in Fig. 2 correspond to those required for co-channel working (30 dB) and adjacent-channel working (20 dB for 15·5 MHz spacing and 14 dB for 19·5 MHz spacing).

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* For example between lines A and B in Appendix 24 of the Radio Regulations[2] which provides a map showing the ITU Regions.

The main use of Fig. 2 is that it indicates the necessary geographical separation of service areas in which co- or adjacent-channels are used, expressed (on the ordinate) in terms of the number of transmitter beamwidths separation from the centre of the beam causing interference to the edge of the service area affected. The transmitter beamwidth is normally taken as the larger of the two beamwidths for the satellite transmissions involved, but in a few cases, the smaller values may impose some additional restrictions; the separation of service areas must therefore, in general, respect the requirements

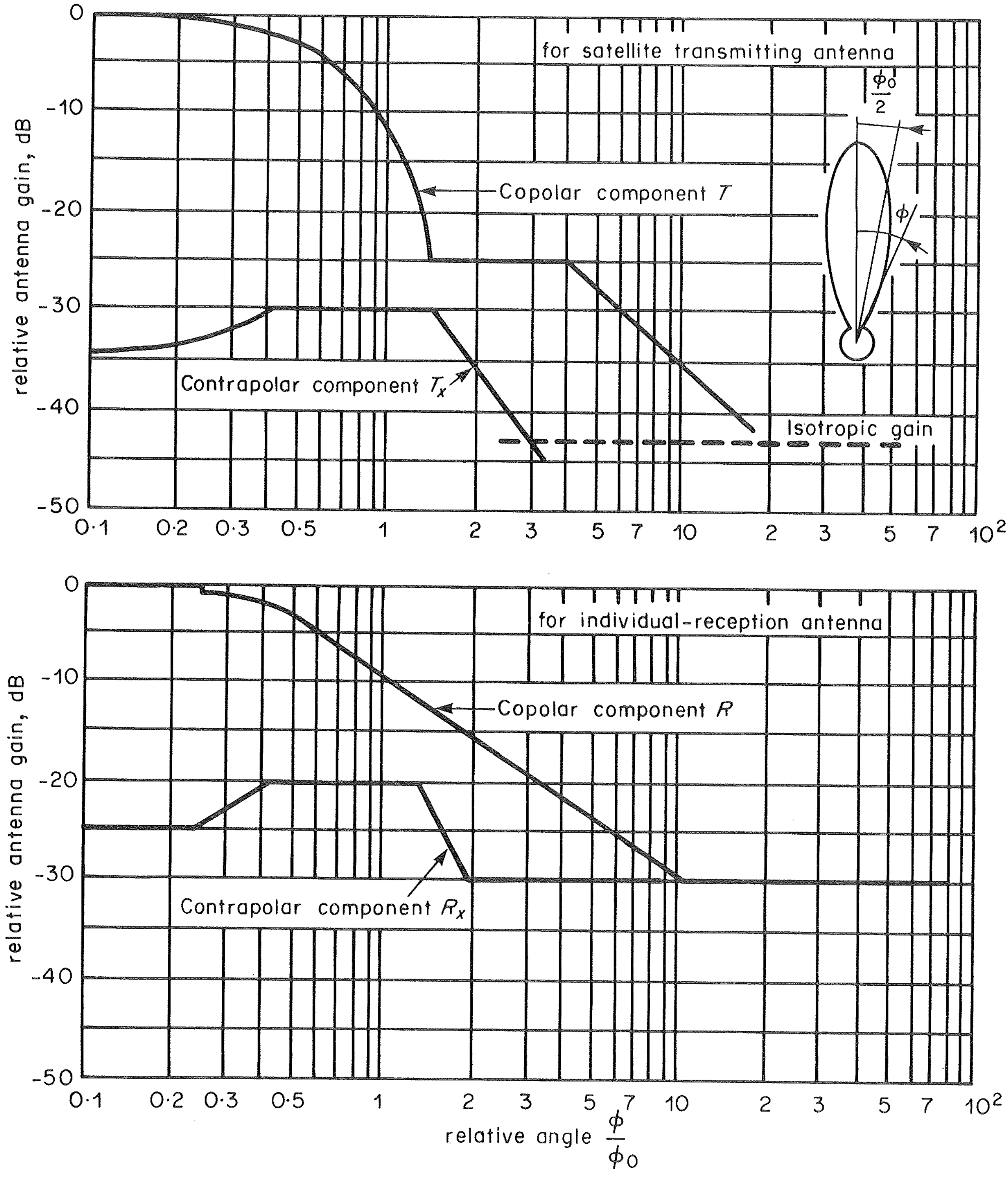

Fig. 1 - Antenna reference patterns

indicated by both beamwidths.

3. Maximum orbital and channel capacity

The foreseeable needs of the part of Region 1 between the lines A and B as defined by the Radio Regulations[2] (Europe and Africa), will probably put as high a demand on the usage of the geostationary orbit and the available frequency channels as the needs in any other part of the world. Thus, in a range of longitude of about 50 degrees, about 100 countries may each require an assignment of five frequency channels (e.g. four television programmes and one multiplex sound signal). On average, therefore, two countries must be assigned a total of ten channels for every degree of longitude.

The ways in which the orbital arc and the frequency band may be suitably shared are discussed in the following paragraphs and some of the resulting alternative solutions are given in Table 1.

The available broadcasting bandwidth of 800 MHz (in Region 1) may be divided into a limited number of separate channels. Each of these channels may be used by a number of different transmissions provided that the ratio of received signal to co-channel interference is at least 30 dB; the circumstances in which this ratio may be achieved can be seen from Fig. 2. For example, if the co-channel countries are spaced well apart, so that the spacing between them is at least 1·8 times the beamwidth required to cover the larger country, then it is possible for them to share the same channel without interference. On the other hand, if the countries are close together so

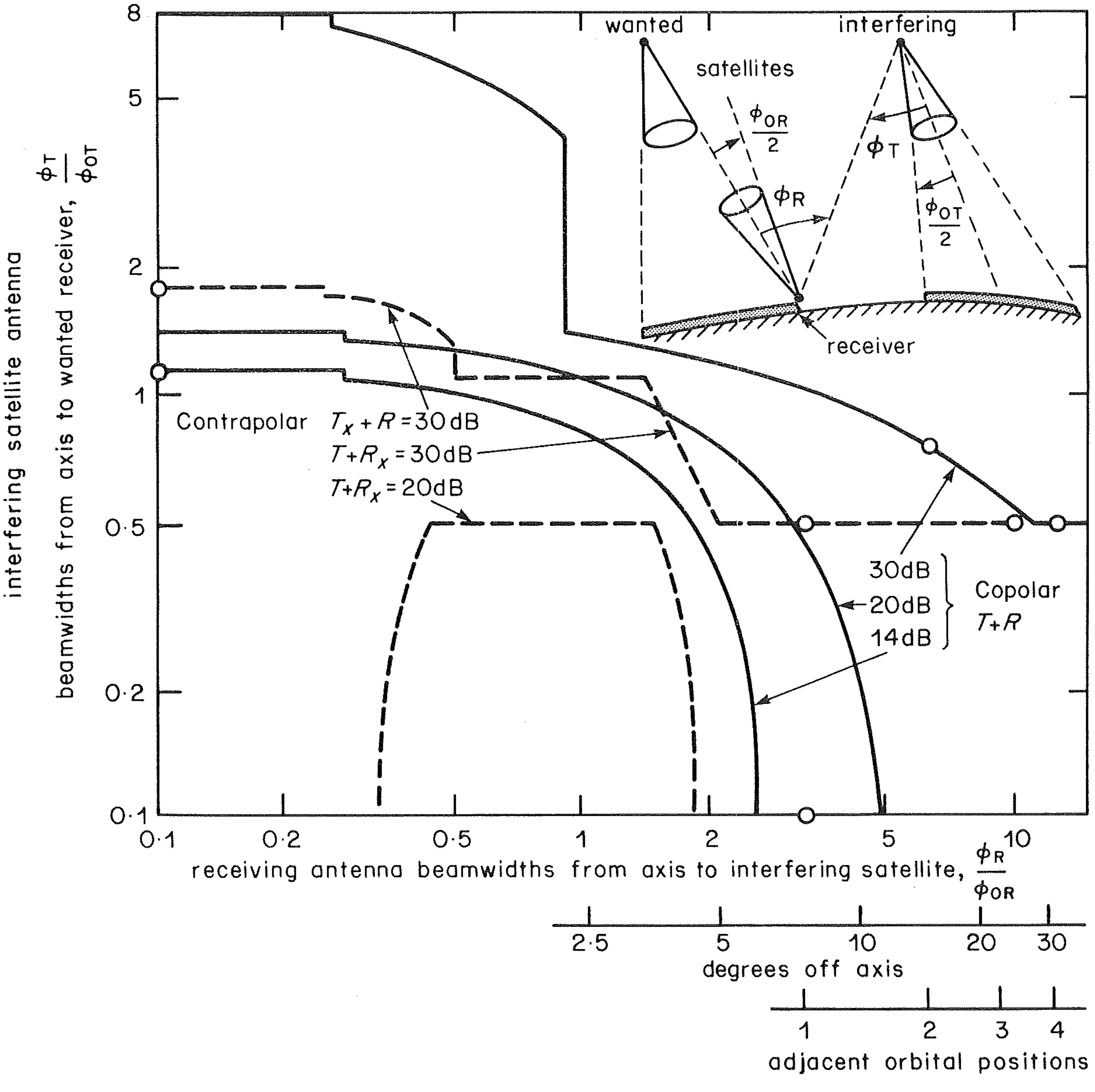

Fig. 2 - Contours of minimum received signal-to-interference ratio at edge of wanted service

TABLE 1

Alternative orbital and channel separation

	Region 1			Region 2, 3	
Width of 12 GHz broadcast band, MHz	800	800	800	500	500
Number of programme channels assigned to each country	5	5	5	4	3
Number of channels required to provide each country with a one-programme service, N	6	8	10	6	8
Total number of channels required	30	40	50	24	24
Channel separation, MHz	26	19·5	15·5	19·5	19·5
Total bandwidth occupied, MHz	780	780	775	468	468
Spare spectrum for guard-bands, MHz	20	20	25	32	32
Co-channel protection ratio, dB	30	30	30	30	30
Adjacent-channel protection ratio, dB	4	14	20	14	14
Orbital position separation,					
degrees of orbital arc	5	7·5	15	7·5	7·5
beamwidths at receiver	2·1	3·1	6·2	3·1	3·1
Countries per degree of orbit	2·4	2·1	1·3	1·6	2·1
Adequate group capacity	no	yes	yes	(two compatible	
Adequate overall capacity	yes	yes	no	options open)	
Preferred system		√			

that their beams overlap, then they cannot share the same channel unless their transmissions come from well-separated orbital positions. While it is accepted that the transmitted beams should provide only national coverage in an economic manner, some groups of adjoining countries may wish to take advantage of a certain degree of inevitable overspill. Thus, near frontier regions, viewing of programmes from neighbouring countries would be made possible with normal receiving equipment if the countries concerned were assigned the same orbital position.

Each member of a group of countries sharing the same satellite position must (unless they are geographically well separated) be assigned a different channel for its first programme. The number of channels, N, required to give all countries a single-programme service is therefore the same as the maximum number of countries in a closely-spaced group which are able to share a common orbital position. Two such groups may, however, share the same channels at a single orbital position provided that there is a large enough separation between thr groups, for example, in the Northern and Southern Hemispheres.

Table 1 gives, for Region 1, three alternative values for the number N, each of which leads to a different total number of channels into which the 800 MHz band must be divided and a different value for the separation between adjacent channels.[6] The adjacent-channel protection ratio is strongly dependent on the channel spacing so that an increase in N rapidly increases the value of the protection ratio required. In these circumstances, the orbital separation must be increased if N is increased in order to minimise the incidence of adjacent-channel interference.

The compromise which must be made in planning is illustrated by the three alternative results given in Table 1 for Region 1. When N is small, a small number of channels is heavily re-used at closely-spaced orbital positions; for larger values of N, fewer orbital positions and a greater number of channels lead to the possibility of larger groups of countries sharing their mutual overspill, but also leads to a smaller overall capability. As can be seen, the second alternative, N=8, seems to be the most attractive compromise.

A similar reasoning leads to the two possibilities given for Regions 2 and 3. The primary consideration is that the channel distribution should be the same, at least for Regions 1 and 3 which must share the same orbital arc for much of their broadcasting needs.

4. Choice of polarisation

With the aid of Fig. 2, it is possible to establish rules for the optimal use of polarisation in a matrix of channels and orbital positions. First of all, co-channel transmissions from the same orbital positions are restricted to being contrapolar. If they were co-polar, Fig. 2 shows that the transmitting beams would require separating by 8 beamwidths, which would render this choice of little general use, whereas contrapolar transmissions require a modest 1·8 beamwidths minimum separation. It will therefore be assumed that each channel may be used only once with each polarisation from each orbital position.

There are now two further independent choices to be made for an area containing closely-spaced countries; these are whether to use the same or alternate polarisations (a) for adjacent channels from the same orbital position and (b) from adjacent orbital positions for the same channel. This leads to four possibilities for a regular channel/orbital position matrix as shown in Table 2, where o and — represent the two polarisations.

TABLE 2

Alternative regular uses of polarisation

Orbital position:		1	2	3	4..	1	2	3	4..	1	2	3	4..	1	2	3	4..
Channel	A	o	o	o	o	o	o	o	o	o	—	o	—	o	—	o	—
	B	o	o	o	o	—	—	—	—	o	—	o	—	—	o	—	o
	C	o	o	o	o	o	o	o	o	o	—	o	—	o	—	o	—
	D	o	o	o	o	—	—	—	—	o	—	o	—	—	o	—	o
		(a) same				(b) alternation by channel				(c) alternation by orbital position				(d) alternation by both			

The selection must be guided by reducing the interference within a closely-spaced group of countries. Whichever matrix is selected, however, the opposite matrix may be used for a second well-separated group of countries.

From Fig. 2, the use of alternate polarisations in adjacent channels is clearly capable of reducing the interference level below that required for adjacent-channel protection for the same orbital position (see left-hand edge of diagram); this favours matrices (b) or (d). It is also clear that co-channel protection (30 dB) is achieved more easily at a closer satellite spacing (5 degrees or 2 beamwidths) with alternate polarisations of adjacent satellites, favouring matrices (c) or (d).

Thus, the polarisation matrix (d) may be selected as the best solution for a close group of countries, while a distant group may use the opposite-polarisation version of matrix (d) from the same orbital position.

5. Distribution of channels, satellites and countries

Fig. 3 shows several channel distributions of which (a), (d), (c), (f) and (g) respectively would correspond to the cases considered in the five columns of Table 1. A sequence $B\overline{A}B$, for example, signifies three adjacent channels of which the B channels each carry one of the programmes for country B, and $\overline{A}$ carries a programme for country A using the opposite polarisation.

In practice, it may be necessary to introduce a few guard-bands at certain points in the channel distribution. For clarity, guard-bands have been omitted from Fig. 3 but the spectrum available for them is shown in Table 1.

It is desirable for instrumental reasons in the receiver that all the channels carrying the programmes for one country are contained within a range of not more than 400 MHz. At the same time, it is necessary to separate them by at least one channel in order to avoid difficulties in multiplexing the signals in the same satellite transmitter. If it proves too expensive to multiplex signals in an $\overline{A}B\overline{A}B$– distribution (such as (d)), it may be necessary to increase the separation and use an $\overline{A}B\overline{C}D$ distribution such as (e), which would also be compatible with the preferred system in Table 1. Although it is tempting to consider a distribution $\overline{A}BC\overline{A}BC$ as in (b), the regular matrix of alternating polarisations cannot be used unless adjacent channels have opposite polarisation, e.g. $\overline{A}B\overline{C}A\overline{B}C$. This would, however, be impracticable because of the need for the viewer to switch polarisations in order to receive all of his own country's programmes.

It may be noted in passing that a polarisation switch may be required, however, for those viewers living close to the common border of two countries sharing a common orbital position who may wish to see a programme of the neighbouring country that is being radiated with the opposite polarisation. In other cases, a viewer may require a receiver with more than 400 MHz tuning range, to permit reception of services from neighbouring countries. Each group of countries must therefore decide on the best division of polarisations, etc. where plans are available which offer a choice; there remains, of course, in all plans, the principle that the simplest receiving installation will be adequate to receive all transmissions intended for one's own country.

A preferred arrangement is indicated at the foot of Table 1 which has the required capacity of two countries per degree of arc and is also capable of serving up to eight countries from one orbital position. This arrangement determines the choice of channel spacing (20 MHz) and orbital position separation (7·5 degrees). The right-hand columns show two options which are open to Regions 2 and 3; these are entirely compatible with that of Region 1 and yet offer them some flexibility in the compromise between the numbers of countries and programmes. Further work may show other possibilities that would be attractive for Regions 2 and 3.

This compatibility between Regions is highly desirable in many parts of the globe where different Regions are

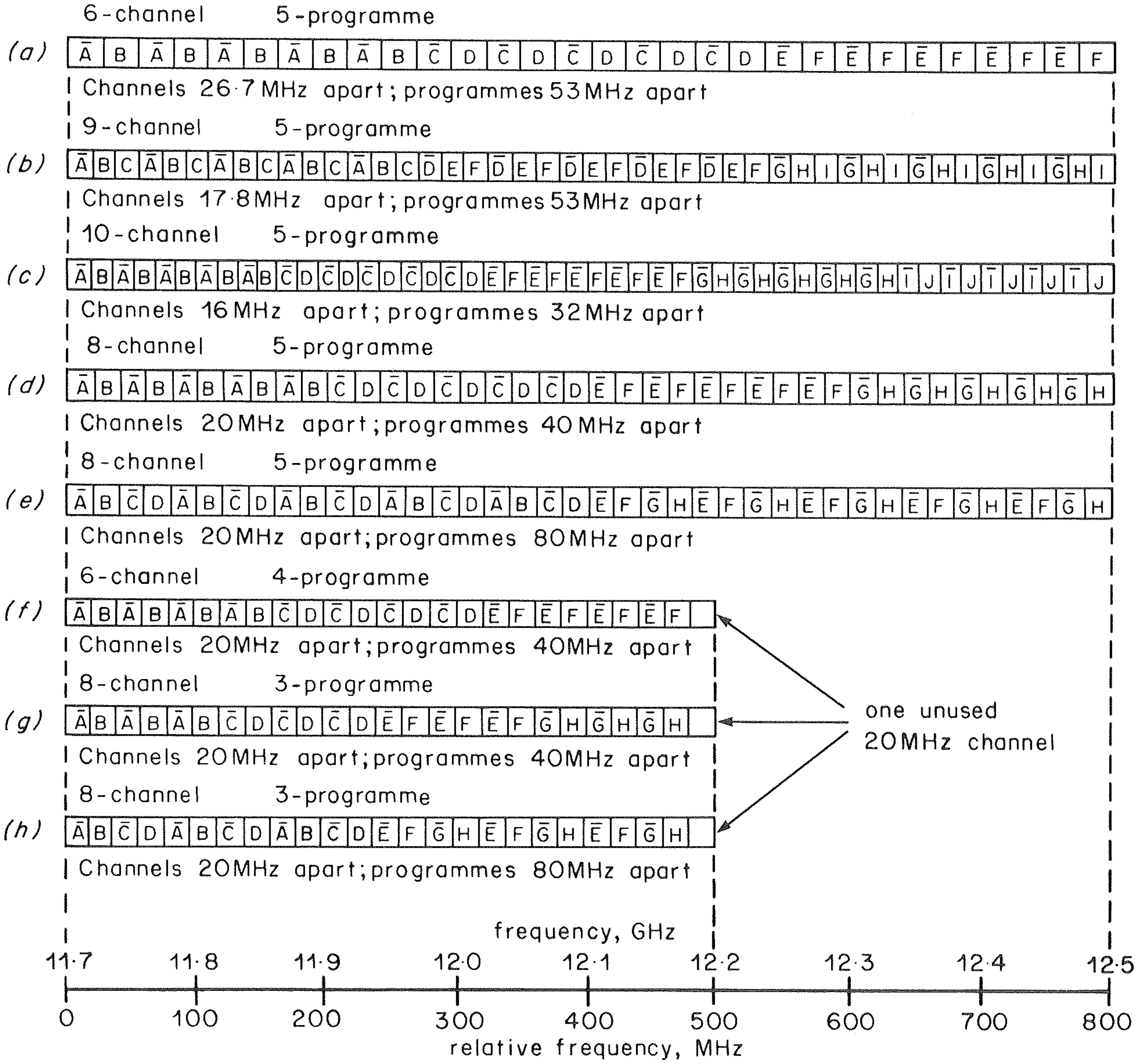
6-channel 5-programme
(a)
Ā B Ā B Ā B Ā B Ā B C̄ D C̄ D C̄ D C̄ D C̄ D Ē F Ē F Ē F Ē F Ē F
Channels 26·7 MHz apart; programmes 53 MHz apart
9-channel 5-programme
(b)
Ā B C Ā B C Ā B C Ā B C Ā B C D̄ E F D̄ E F D̄ E F D̄ E F D̄ E F Ḡ H I Ḡ H I Ḡ H I Ḡ H I Ḡ H I
Channels 17·8 MHz apart; programmes 53 MHz apart
10-channel 5-programme
(c)
Ā B Ā B Ā B Ā B Ā B C̄ D C̄ D C̄ D C̄ D C̄ D Ē F Ē F Ē F Ē F Ē F Ḡ H Ḡ H Ḡ H Ḡ H Ḡ H Ī J Ī J Ī J Ī J Ī J
Channels 16 MHz apart; programmes 32 MHz apart
8-channel 5-programme
(d)
Ā B Ā B Ā B Ā B Ā B C̄ D C̄ D C̄ D C̄ D C̄ D Ē F Ē F Ē F Ē F Ē F Ḡ H Ḡ H Ḡ H Ḡ H Ḡ H
Channels 20 MHz apart; programmes 40 MHz apart
8-channel 5-programme
(e)
Ā B C̄ D Ā B C̄ D Ā B C̄ D Ā B C̄ D Ā B C̄ D Ē F Ḡ H Ē F Ḡ H Ē F Ḡ H Ē F Ḡ H Ē F Ḡ H
Channels 20 MHz apart; programmes 80 MHz apart
6-channel 4-programme
(f)
Ā B Ā B Ā B Ā B C̄ D C̄ D C̄ D C̄ D Ē F Ē F Ē F Ē F
Channels 20 MHz apart; programmes 40 MHz apart
8-channel 3-programme
(g)
Ā B Ā B Ā B C̄ D C̄ D C̄ D Ē F Ē F Ē F Ḡ H Ḡ H Ḡ H
Channels 20 MHz apart; programmes 40 MHz apart
8-channel 3-programme
(h)
Ā B C̄ D Ā B C̄ D Ā B C̄ D Ē F Ḡ H Ē F Ḡ H Ē F Ḡ H
Channels 20 MHz apart; programmes 80 MHz apart
one unused 20 MHz channel
frequency, GHz
11·7
11·8
11·9
12·0
12·1
12·2
12·3
12·4
12·5
0
100
200
300
400
500
600
700
800
relative frequency, MHz

Fig. 3 - Regular channel distributions

(a) to (e) Alternatives for ITU Region 1
(d) and (e) Preferred for ITU Region 1
(f) to (h) Compatible options for ITU Regions 2 and 3
(g) and (h) Preferred for ITU Regions 2 and 3

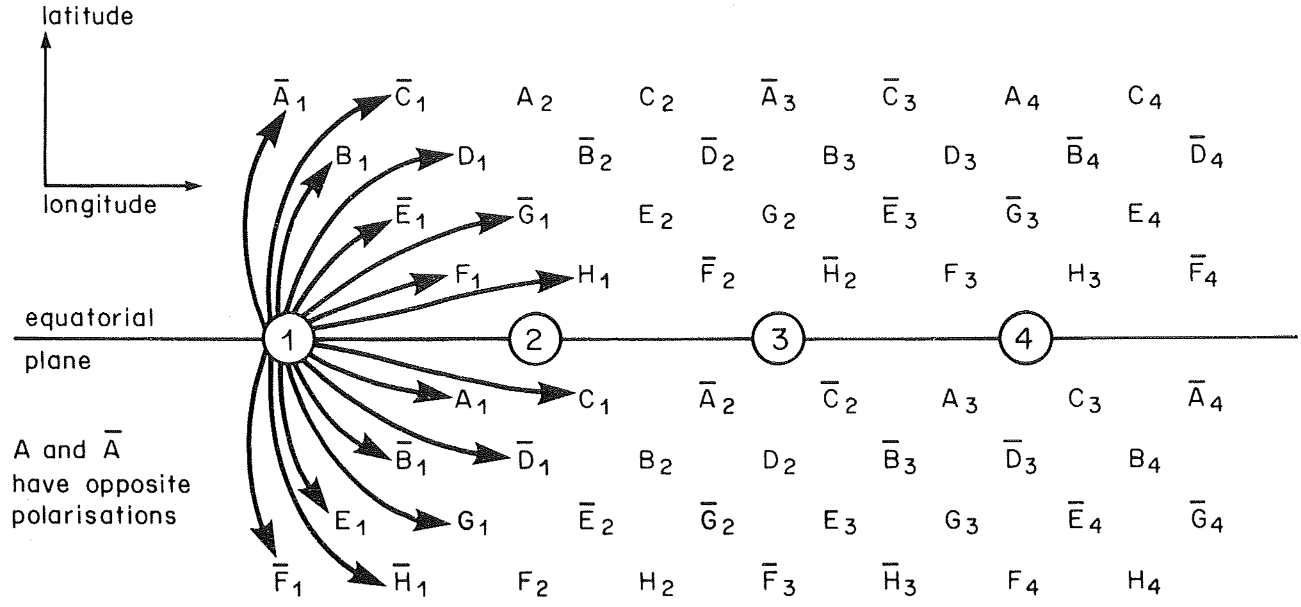

Fig. 4 - A generalised distribution of orbital positions, countries and channels

forced to use the same part of the geostationary orbit. For example, India, in Region 3, the USSR, in Region 1, will share the use of the orbit between the longitudes of say 50°E and 75°E. USSR services could operate up to 12·5 GHz as in Europe but India would be restricted to a 500 MHz band up to 12·2 GHz and a distribution chosen from (f), (g) or (h) in Fig. 3. A large country with many languages, such as India, or with many time zones could be regarded (like the Western European group) as a group of countries for planning purposes. Ideally, India would want a separate television programme for each of its 22 distinct cultures. This may be possible by using either 6 beams of 4 programmes each or 8 beams of 3 programmes each. (The choice between television and multiplex sound for any of the channels remains as a national decision). The needs of a country in one Region may be entirely compatible with those of another Region using the same orbit, but there will be problems, in areas of overlap between Regions, where different numbers of programmes per country may lead to some additional risk of interference. It is to be hoped that these problems might be resolved by judicious use of spare assignments.

For Region 1, in particular, Fig. 4 illustrates an idealised geographical distribution of countries showing the channels, polarisations and orbital positions which serve them taking, as an example, one of the two 8-channel distributions shown in Fig. 3(d) or (e). As can be seen, Fig. 4 embodies the polarisation alternation suggested in Section 4, and the re-use of channels with opposite polarisation at the same orbital positions for well-separated countries, such as B_1 and $\bar{B}_1$, as suggested in Section 3.

The use of essentially regular distributions of channels, polarisations and positions, as illustrated by Fig. 4, thus provides a good starting point for making trial assignments. The advantages of this method are that the rules by which assignments are made are simple to test and the consequences of modifying a plan of assignments are easier to assess. This simplification will be described with the help of Fig. 5.

6. Simplified data for plan synthesis

The essential data for making assignments to a particular arrangement of countries is given in Fig. 5. The notation used is such that B_3 means channel group B used from satellite position number 3, the bar means the use of the opposite polarisation. The diagram shows the necessary separation between two countries (expressed in transmitting antenna beamwidths) which is sufficient to allow it to take a particular place in the framework decided by the foregoing rules. Fig. 5 is simplified to show only a pair of adjacent channels (A and B) as an example and, bearing in mind the in-filling provided by other channels, the allowances appear to be of adequate magnitude for the generalised geographical distribution given in Fig. 4.

For example, adjacent countries $\bar{A}_1$ and B_1 require no separation; similarly B_1 and $\bar{C}_1$ etc., up to the maximum number, N, of countries sharing orbital position number 1. Some care is required, however, in assigning the same channel to countries of neighbouring groups in the same hemisphere such as, for example, B_1 and $\bar{B}_2$ which require a minimum separation of 0·5 beamwidths. The same considerations apply to interference between A_1, $\bar{B}_1$ and B_2 in the lower half of the diagram.

Well-separated groups, such as $\bar{A}_1$ B_1 and A_1 $\bar{B}_1$ however require a separation of up to 1·8 beamwidths. In the gap between these groups, there will be other countries; these will have to be served from an adjacent orbital position if the two groups have filled all the permissible 2N assignments. In this unlikely event, it may be possible to re-use channel B_1 (with the same polarisation and satellite position) for, say, country B'_1 provided that the separation between the two is at least 8 beamwidths; this possibility is not shown in Fig. 5 as it would be an irregularity.

Assignments may therefore be made for each country after checking that countries using the same and adjacent channels have the necessary separation, as given by the set of numbers in Fig. 5. It is possible to build up a complete plan manually from this data, using the appropriate maps showing each national boundary on a satellite projection.[7] Manual plan synthesis can be speedy, easily modified and fairly accurate, but is not able to take into account easily all of the necessary factors.

To make accurate plans, a great deal of data is required about the aiming points and optimum beam shapes for the transmission to each country. This data will be different for each orbital position and an allowance must be made for the limited pointing stability (±0·1 degree) of the satellite antenna. The satellite antenna must also be limited in size for economic reasons, leading to a size which gives a minimum beam radius of 0·3 degrees. The e.i.r.p. required is generally the same on the axis of each beam but countries which are smaller than the minimum beam size would in general be assumed to use a smaller e.i.r.p. at their beam centre just giving an adequate e.i.r.p. at the limit of their area. On the other hand, countries with latitudes extending to 70 degrees or more would need a greater e.i.r.p. in order to overcome the greater atmospheric attenuation[5] at the smaller angle of arrival of the signal. This latter problem can be partially solved by changing the aiming point as suggested by Millington.[8] Finally, the interference level on which each possible assignment is judged must be the total interference from all sources and not simply that of the worst offender.

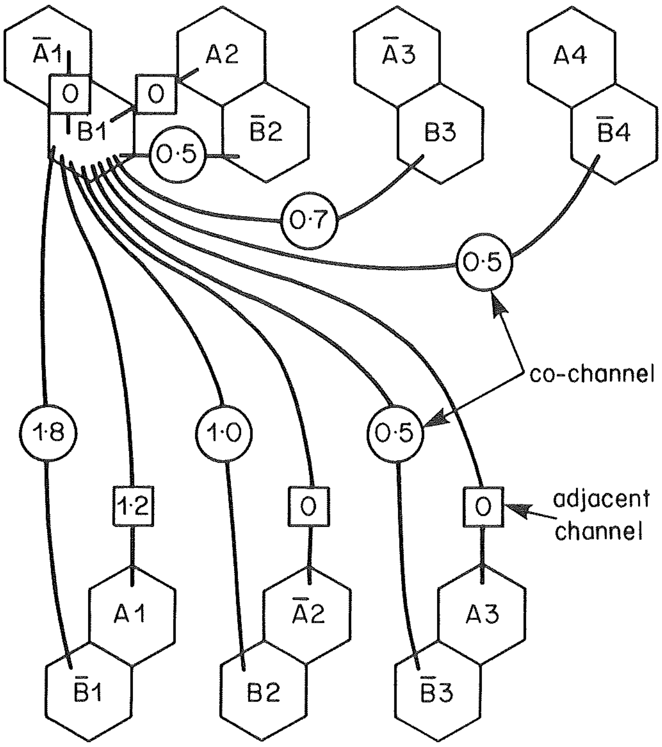

Fig. 5 - Separation in beamwidths required between beams to co-channel and adjacent channel countries in part of the distribution of Fig. 4.

Analysis by computer is essential for all these factors to be accounted for. Synthesis of a plan is probably best accomplished by a process of successive approximation from a manual plan, combined with piecemeal analysis. Whatever method is adopted, the use of a structure of regular distributions, similar to that described here, results in a worthwhile simplification in preparing and modifying a plan.

The antenna reference patterns, from which the optimum distributions have been deduced, can now be reviewed so as to find whether relaxations can be made in those areas of performance which are not invoked by the chosen distributions. Modifications to the antenna reference patterns will occur as technology changes. In fact, a recently-submitted revision to the CCIR data[5] suggests an improvement in performance in both receiving and transmitting antennas. If these changes were taken into account in preparing a revised version of Fig. 5, the relaxation in the required minimum separation between countries would be small, as indicated in the Appendix, Section 10, and Fig. 7.

7. Reconstructed antenna reference patterns

Returning to Fig. 2, the data which have been used in preparing optimised rules for planning can be represented by a series of points at the intersections of the appropriate curves with verticals through the abscissa corresponding to the preferred choice for Region 1 in Table 1. If these points are transferred back to the original format of Fig. 1, we may draw curves through these points, as in Fig. 6, to represent the acceptable limits of antenna performance for the purpose of this planning structure. The shading of Fig. 6 shows the areas where the original performance could be relaxed without causing unacceptable interference within a satellite broadcasting plan.

Fig. 6 reveals some interesting features. First, the on-axis contrapolar components of both antennae could be reduced to about 20 dB. Second, the off-axis data for the receiving antenna is most important at angles of 3 beamwidths or more but, for the transmitting antenna, no improvement is required beyond about 2 beamwidths.

It must be remembered, however, that any relaxation of the transmitting or receiving antenna requirements may affect interference to or from terrestrial services in the band; this aspect of interference is not discussed here.

Most striking of all is the conclusion that, if greater discrimination is necessary, it is the off-axis attenuation of the receiving antenna which must be improved first. For example, at about 3 beamwidths (7·5 degrees) a receiving antenna attenuation of 35 dB would be of great benefit.

In seeking a better performance for the receiving antenna, it should be remembered that the discrimination is required mainly along the orbital arc containing the satellite transmitters and, ideally, at regular intervals only. Thus, the receiving antenna designer should not interpret the reference patterns of Figs. 1 and 6 as requiring axial symmetry but might be allowed a less restrictive pattern in a plane normal to the orbital arc.

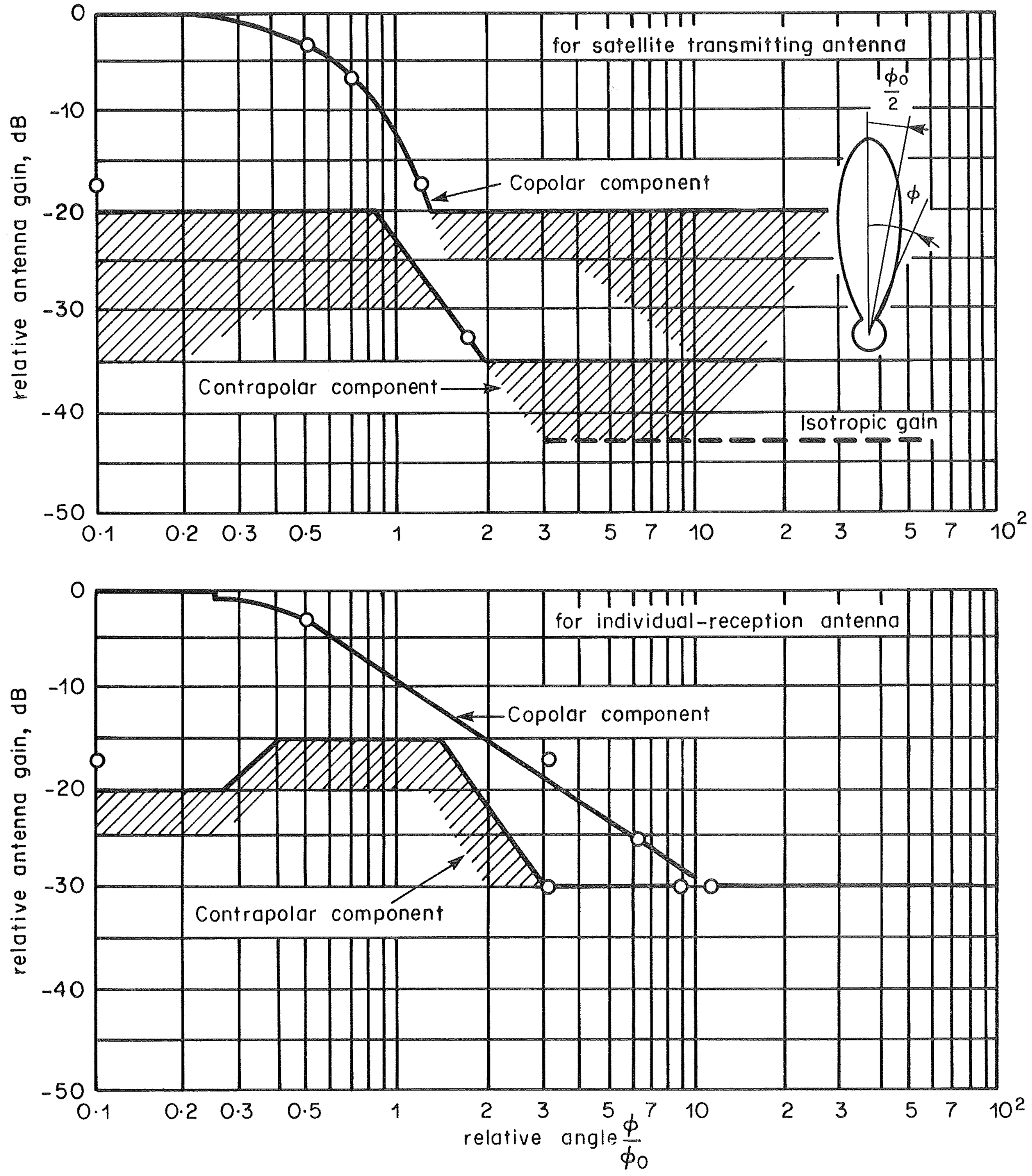

Fig. 6 - Antenna reference patterns reconstructed from Figs. 1 and 2

adequate performance

essential points

possible relaxation from original data

8. Discussion and conclusion

A consideration of the basic data for satellite broadcast planning has suggested the formulation of a set of rules. These rules enable most of the alternative choices to be fixed at the start, leading to a small number of alternative sets of regular distributions of channels, orbital positions and polarisations. From these sets an optimum can be selected for each region.

A search for a systematic arrangement of channels, satellites and polarisations has simplified the desirable features of the antenna patterns. Without prejudice to the original data on which the arguments have been based, it may be that simpler antennae would serve the purpose equally well.

As can be seen from Fig. 6 the transmitting antenna pattern may be relaxed in many places, which may seem an unfortunate loss of potential in the space sector. Rain depolarisation limits any worthwhile improvement in the on-axis contrapolar performance of the satellite antenna but the space sector could make a more useful contribution by improving its attitude stability. On the other hand, if a slightly better performance can be achieved for the individual domestic receiving antenna as suggested in Section 7, a valuable improvement would result. The latter suggestion appears to put extra costs on the domestic sector but this might not be significant if the orbital separation were fixed, as proposed, so that a single antenna design would be sufficient for a whole region.

9. References

1. International Telecommunication Union. The final acts of the World Administrative Radio Conference for Space Telecommunications, Geneva, 1971, Annexe 3, Article 5, page 103.
2. International Telecommunication Union. Radio Regulations, Geneva 1968. (with revisions 1971).
3. PHILLIPS, G.J. 1970. Satellite broadcasting: spectrum efficiency of television services in the 12 GHz band. BBC Research Department Report No. 1970/38.
4. MERTENS, H. 1975. The evaluation of interference in a plan for satellite broadcasting in the 12 GHz band. EBU Review – Technical No. 153.
5. CCIR Report 215/3. XIIIth Plenary Assembly, Geneva 1974, Vol. XI, p. 174. (See also Doc. 11/258, Geneva, 1976).
6. GILCHRIST, N.H.C. 1974. Satellite broadcasting: channel separation requirements for f.m. television signals. BBC Research Department Report No. 1974/20.
7. LAVEN, P.A. *and* LEE, R.W. 1975. Map projections for planning of broadcast services: use of a digital computer. BBC Research Department Report No. 1975/21.
8. MILLINGTON, G. 1975. Geostationary-satellite earth coverage. Proc. IEE Vol. 122, No. 2, February 1975.

10. APPENDIX

The effect of the current revision of antenna reference patterns by the CCIR

The numbers of beamwidths necessary between two countries is given in Fig. 7, based on the revised antenna reference patterns currently being proposed by the CCIR.[5] It shows a small relaxation in planning constraints compared with Fig. 5 which was based on EBU planning data at the time of writing. Probably the most significant effect of this relaxation is the reduction of 3 dB in the contribution to co-channel interference between satellites spaced by 20 degrees or more.

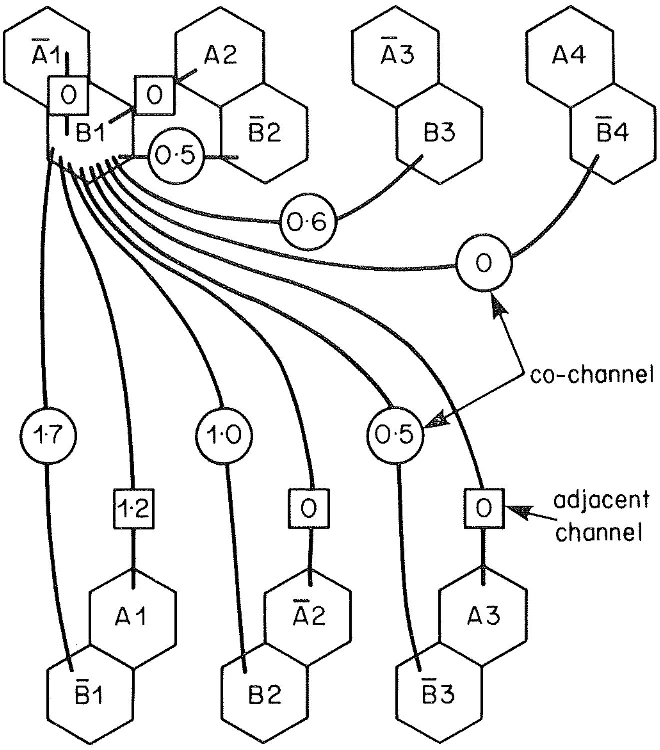

Fig. 7 - Required separation in beamwidths between countries using revised CCIR data; see Section 6 and compare Fig. 5

HR/AM

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